September 2003 ECN-C--03-090

ANALYSIS OF THE FEASIBILITY OF INCLUSION OF DECENTRALISED RENEWABLE ELECTRICTY SYSTEMS INTO A MANDATED MARKET SHARE MECHANISM FOR CHINA

Executive Summary

N.H. van der Linden, ECN
L. Junfeng, NDRC Energy Research Institute
D. Keyun, China Association of Rural Energy Industry
J.W. Martens, EcoSecurities
K.V. Ramani
W. Sicheng, Beijing Jike Energy New Development Co.
W. Shutian, Beijing Tianhen Renewable Energy Co.Ltd.
C. van der Tak, NCC Consultancy BV

Acknowledgement
From June 2002 to September 2003 a team led by the Energy research Institute of the Netherlands (ECN) consisting of experts from China and Europe has been working to assess the feasibility of inclusion of decentralised renewable electricity systems (DRES) into the proposed Mandated Market Share (MMS) mechanism for China. The work was supported by the Department for International Development of the UK Government. The full report on which this Executive Summary is based on a 146 page document (ECN-C--03-089), which has been written for the technical reader. The report can be downloaded from the Internet at www.ecn.nl.

The project is registered under ECN project number 7. 7440.

This document is an output from a project funded by the UK Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of DFID.

Abstract
The World Bank and the Global Environment Facility provide assistance to the Government of China with the implementation of the renewable energy programme during the 10th and 11th Five Year Plans. To this end, the China Renewable Energy Scale-up Programme (CRESP) was set up. CRESP is managed by the Project Management Office (PMO), which is institutionally placed in the National Development and Planning Commission (NDRC). One of the first activities initiated by CRESP is the development of the institutional framework within which the Mandated Market System (MMS) policy for renewable energy can be introduced.

An MMS policy is based on the requirement that a set amount (or proportion) of the electricity supply is produced from renewable energy sources. The obligation is placed at some point in the supply chain, which could range from production, through transmission to supply or consumption. Monitoring procedures are put in place to ensure that the obligation will be met. Environmental considerations are the main reason behind the intention to introduce an MMS in China but the government has also recognised the importance of (renewable) energy to achieving poverty objectives.

Decentralised renewable electricity systems (DRES) have special relevance for rural poor communities that are unserved or underserved by centralised fossil fuel networks or utility electricity grids. DRES may offer a promising solution to meet demand for energy services of these communities in remote location, which cannot be reach by the electricity grid. The analysis in this study focused on mini-hydro (less than 10 kW), solar home systems and stand-alone wind turbines.

The principal objective of the study is to analyse the feasibility of inclusion of DRES into the proposed MMS for China. Because DRES are often used in remote areas, which are difficult to reach, the costs of verifying these systems are prohibitive if the procedures are not sufficiently simple and efficient. Therefore, simplified procedures have been developed for verifying the number of DRES sold and the operational status of the systems.

The analyses shows that inclusion of stand alone PV and wind into the MMS is not feasible because the required verification procedures for these technologies appear to be too costly and the additional electricity generated is only significant if the premium price of wind and PV is some 100 times higher compared to grid connected RE technologies. For mini-hydro, however, it is concluded that inclusion into the MMS is feasible and recommendable.

CONTENTS

ACRONYMS

AMB	Agricultural Machinery Bureau
CRESP	China Renewable Energy Scale-up Programme
DRE	Decentralised Renewable Electricity
MMS	Mandated Market Share
NDRC	National Planning and Reform Commission (SETC and SDPC have merged into newly established NDRC)
RE	Renewable Energy
REDP	Renewable Energy Development Programme
RMB	Renminbi (Chinese currency)
RPS	Renewable Portfolio Standard
SHS	Solar Home System
WTP	Willingness To Pay

CONVERSION FACTOR

1 $US = 8.28 Yuan Renminbi

1. INTRODUCTION

China's remarkable achievements in the deployment of renewable energy have long been recognized world-wide, in particular its small hydropower and biogas programmes are regularly cited as models of success and are used in many other countries. China has already expressed its intention to increase further the deployment of renewable energy to help achieve sustainable economic development and reduce the environmental impact from the use of coal. A major programme for renewable energy will be implemented as part of the Tenth Five Year Plan (2001-2006) and will be continued in the 11th Five Year Plan.

The World Bank and the Global Environment Facility provide assistance to the Government of China with the implementation of the renewable energy programme during the 10th and 11th Five Year Plans. To this end, the China Renewable Energy Scale-up Programme (CRESP) was set up. CRESP is managed by the Project Management Office (PMO), which is institutionally placed in the National Development and Reform Commission (NDRC). One of the first activities initiated by CRESP is the development of the institutional framework within which the MMS policy for renewable energy can be introduced.

An MMS policy is based on the requirement that a set amount (or proportion) of the electricity supply is produced from renewable energy sources. The obligation is placed at some point in the supply chain, which could range from production, through transmission to supply or consumption. Monitoring procedures are put in place to ensure that the obligation will be met. For grid connected renewable energy technologies the monitoring basically involves meter reading.

In an MMS, the producers of renewable electricity receive a premium price to cover the marginal costs of producing electricity from renewable sources. These costs are usually passed on to the electricity consumers either compulsorily (i.e. costs are added to the usual price of electricity) or voluntarily (i.e. via green electricity schemes, where environmentally aware consumers pay extra voluntarily). This means that within an MMS an additional stream of revenues is generated to support the production of electricity from renewable energy sources.

In general, MMS systems can be built by using one (or a combination) of the following three types of support instruments.
1. Renewable Portfolio Standard (RPS): the government sets by law (or voluntarily) the amount (or proportion) of electricity supply that must be produced from renewable sources; the market is then allowed to set the price of meeting this obligation by trade.
2. Feed In Tariffs: all qualified electricity generated from renewable sources is paid a premium price set by the government on delivery to the grid.
3. Tendering System: government sets up a fund to pay the cost of its renewable energy support policy. The system involves a competitive bidding process for access to the fund to ensure that only the most cost-effective projects gain access to the fund.

MMS-type systems have already been introduced in several European countries and in a number of states in the USA as a means to achieve environmental objectives and to diversify the energy supply mix. The Government of China is currently examining whether an MMS would be an appropriate policy framework for China to accelerate the use of renewable energy in order to reduce the environmental pollution. This also includes an analysis of what would be the best support instrument in the Chinese situation. Like in Europe and the USA, the focus of the proposed MMS for China will be on grid connected renewable energy technologies.

Environmental considerations are the main reason behind the intention to introduce an MMS in China but the government has also recognised the importance of (renewable) energy to achieving poverty objectives. The linkage between energy and poverty has been spotlighted in the wake of recent international attention to the persistent problem of poverty in developing countries. The most serious and organised expressions of interest in the energy-poverty nexus are now set within the framework of the 'millennium development goals' and the outcomes of the World Summit on Sustainable Development, 2002. With the majority of the world's poor living in rural areas, this implicitly means a re-examination of policies and strategies to promote modern fuels and electricity for rural socio-economic development.

Decentralised renewable electricity systems (DRES) have special relevance for rural poor communities that are unserved or underserved by centralised fossil fuel networks or utility electricity grids. DRES may offer a promising solution to meet demand for energy services of these communities in remote locations, which cannot be reached by the electricity grid. At present, there are some 30,000 villages in China, with an average population of approximately 1,000 people per village, without access to electricity. These villages are likely to continue receiving low priority for grid extension because of their remote location and their low electricity consumption. The Government of China has set itself the task of electrifying these remote villages, to which grid extension is not feasible, by DRES.

However, there are several barriers that prevent a rapid introduction of DRES. The most serious barrier is the problem of affordability. DRES are usually cost-competitive against conventional energy options in serving remote communities. Especially when small quantities of energy are required, DRES are often the least cost option. However, while communities living in remote areas may find DRES their cheapest option, the vast majority of the poor lead a subsistence life and lacks enough cash to purchase DRES to improve their living conditions and enhance their livelihoods.

One of the options to reduce this barrier that is currently being considered by the Chinese government is to include DRES into the proposed MMS for China. If DRES could be brought under the MMS, part of the revenue stream generated within the MMS could be allocated for DRES which in turn could be used to increase the access of the poor to DRES through a price reduction or the provision of better and less expensive maintenance services.

However, because DRES are stand-alone systems generally producing only small amounts of electricity, these systems do not have an electricity meter. Therefore, if these systems are to be included into the MMS, monitoring cannot be done simply by reading the meter but separate procedures need to be developed and implemented to monitor and verify the total amount of electricity produced by these systems. The transaction costs associated with these procedures to a large extent determine the feasibility of including DRES into MMS as an option to improve access to electricity in poor rural areas in China.

The present study aims to identify suitable monitoring and verification procedures for DRES and to assess the feasibility of including DRES into the proposed MMS for China. The key question addressed in the study is to what extent the MMS policy framework that is proposed to achieving environmental objectives can also be used to contribute to meeting poverty objectives by promoting DRES.

The results of this study contribute to the design of an MMS for China, which is a separate activity initiated by CRESP, in the sense that this study recommends on the type of provision that must be made within the MMS to ensure a significant improvement of the access of the poor to electricity services.

2. STUDY BOUNDARIES

The principal objective of the study is to analyse the feasibility of inclusion of decentralised renewable electricity systems into the proposed MMS for China. In order to achieve this objective within the time and resources that were available to the project team, the scope of the study had to be clearly focussed. The following main assumptions delineate the study boundaries.

Mandated Market Share Policy Framework

For each of the three support mechanisms that can be used to build an MMS (feed-in, RPS, tender procedure) one needs to set up an accounting framework to track, monitor and verify the amount of electricity produced from renewable energy sources. In this study the accounting framework is defined as the *green certificate* system. In the green certificate system producers of renewable electricity receive a certificate for each pre-defined unit of electricity produced (for example, for each MWh). Such certificates represent the 'greenness' of the electricity produced and promotes the creation of two different markets: the market of physical electricity, and the market of green certificates. The price of a green certificate determines the amount of additional revenues that can be generated to cover the marginal costs of producing electricity from renewable sources.

Selection of target province

Because of limited resources, the analysis presented in this report focuses on the province of Sichuan and these results have been, in as far as possible, extrapolated to the national level by way of an extrapolation method taking into account the variations in income level, electrification rate, renewable energy resources and technology costs, for the different provinces. Based on criteria such as the extent to which the province is representative of the western provinces in China, the available renewable sources, electrification rate, available data and support of the provincial government it was decided to focus the analysis on the province of Sichuan.

Selection of technologies

The decentralised renewable electricity technologies that could potentially be included into the MMS are given in Appendix A. In Table 2.1 these technologies are grouped into two main categories: technologies that are not metered and technologies that have an electricity meter. The latter group includes the PV villages systems. Currently, some 1,000 village PV power systems with 18,000 kW_p have been installed. The group of non metered technologies was further subdivided into technologies for individual household application and technologies for commercial application.

Table 2.1 *Categorisation of decentralised electricity technologies in China*

	Not metered		*Metered*
	Individual household systems	Commercial stand-alone (incl. Water pumping)	Mini-grids
PV	10 - 200 W_p	200 - 2000 W_p	5 - 100 kW
PV - Wind hybrid system	100 W wind/50 W PV 300 W wind/100/200 W PV		Up to 500 kW (2./3 wind-1/3 PV)
Mini hydro*	< 10 kW	Variable	
Wind	50 - 300 W	500W - 10 kW	

* Mini hydro is defined as installations in the range of .1-10 kW. This definition is taken from (Zhang Zhengmin et al).

The distinction between metered and non-metered electricity is important for the development of monitoring procedures for the system performance. If DRE systems are metered, separate procedures for monitoring the system performance are not needed. The subdivision of non metered technologies is relevant for determining the poverty impact of inclusion into MMS, which may differ for household applications and commercial applications.

Assessment of the potential market for decentralised renewable electricity technologies.

The assessment of the potential market in China for non metered DRE systems involves an estimation of the following variables:

- The number of households not yet electrified; these households could potentially purchase a renewable electricity stand-alone system.
- The number of households which already have a system but with low capacity or poor performance; these households could potentially replace the existing system by a new system.

Table 2.2 and Table 2.3 show the currently installed and potential market for new DRE systems in China and in Suchuan province.

Table 2.2 *Currently installed and potential market for new DRE systems in Sichuan*

Market segment	Currently installed systems in Sichuan		
	PV	Wind	Mini-hydro
Stand alone systems	20,000		8,000
Mini-grids	50 villages		None
	Potential market for new systems in Sichuan		
	PV	Wind	Mini-hydro
Unelectrified hsh	118,000		226,000
Replacement	5,000		8,000
New mini grids	2,000 (10 MW_p)		none

Table 2.3 *Currently installed and potential market for new DRE systems in China*

Market segment	Currently installed systems in China		
	PV	Wind	Mini-hydro
Stand alone systems	300,000	170,000	146,000
Mini-grids	1,000 villages		None
	Potential market for new systems in China		
	PV	Wind	Mini-hydro
Unelectrified hsh	2,000,000	992,000	581,000
Replacement	100,000	85,000	146,000
New mini grids	20,000 villages (100 MW_p)		

3. RENEWABLE ENERGY DEVELOPMENT IN CHINA

The first applications in China of decentralised electricity systems based on renewable energy sources took place in the early seventies. During the past three decades these systems went through the various development stages of technological research and design, demonstration, promotion, standardisation and serial production and have now reached maturity. Initially, the main application was for communication but gradually the focus shifted to the provision of electricity in remote areas that cannot be covered by the central electricity grid. After three decades of Government supported research and as a result of the high priority given by the Chinese government to rural electrification these systems have developed into mature technologies and the installed capacity is rapidly growing. Technological developments and a substantial increase in sales volume have brought down the cost of these systems on average by a factor of 10 over the past three decades.

Mini-hydro (less than 10 kW) is the most important decentralised electricity technology in China in terms of resource availability and installed capacity. At present, total installed mini hydro capacity is 154 MW and the potential exploitable resources are estimated to amount to 80 GW. Currently some 146,000 mini hydro systems have been installed in China and the potential market for new systems is estimated to amount to some 420,000 installations. The average price for a system is around 5,000 RMB/kW.

Solar photovoltaic is a fast growing technology in China, both for household applications as well as for powering mini grids. In 2002, total installed PV capacity amounted to some 25 MW, mostly used for rural electrification. PV sales grew rapidly during the last decade from some 3,880 kW_p in 1993 to some 20,000 kW_p in 2002. The price per W_p over the same period went down from RMB 40-47 to RMB 30-40. At present, some 300,000 PV systems have been installed in China and the estimated potential market for new systems exceeds 2 million units. The price of the most common 18-20 W PV system is about 1,600 RMB and includes the PV panel, the 12V/38 Ah battery, the controller, 3 sets DC lights and cabling.

Stand alone wind turbines are currently mainly used in Inner Mongolia for supplying electricity to nomadic people. At present some 178,000 systems are still operational in China with a total capacity of 16 MW. Some 80% of these systems can be found in Inner Mongolia. The most common size is in the range of 150-300 W, which generates 250-380 kWh annually and costs RMB 1,150-3,090.

Based on the above review of DRE-systems in China, mini hydro (less than 10 kW), photovoltaic (both household applications as well as mini grids) and small wind technologies will be considered for inclusion into the MMS. A detailed list of the various types of systems is presented in Appendix A

4. STREAMLINED PROCEDURES FOR MONITORING AND VERIFICATION OF DRE TECHNOLOGIES

In the MMS schemes for renewable electricity, which have been implemented in different countries, monitoring and verification procedures have hardly been an issue. They have all taken place in countries with near 100% grid connection and hence involved only grid-connected renewable energy systems[1]. Grid connected renewable electricity is automatically monitored by the grid operators and/or distribution companies; hence verification has not been an issue.

Decentralised renewable electricity systems, on the other hand, are by definition not connected to the national (regional) electricity grid and, consequently, the amount of electricity produced by these systems will not be automatically measured. Therefore, if these systems are to be included into the MMS, separate procedures need to be developed and implemented to monitor and verify the total amount of electricity produced by these systems. The focus will be on non-metered decentralised technologies (see Table 2.1) because isolated mini grids that are metered follow the standard reporting practices as grid connected power generators.

Because DRE-systems are often used in remote areas that are difficult to reach, the costs of monitoring and verifying these systems are prohibitive if the procedures are not sufficiently simple and efficient. Therefore, simplified procedures have been developed for the following variables that need to be monitored and verified in order to correctly establish the amount of electricity produced by the DRE system:

1. *Estimating average kWh production* of DRE-systems. For each DRE technology, a simple formula has been established to determine the kWh production of the system. The production is determined by the technology, the size of the system, the resource availability in the region where the system is used and by the estimated demand load of the system.
2. *Verifying the volume of DRE-system sales*. The number of systems sold by the equipment supplier determines the amount of green certificates the supplier can claim from the body that oversees the MMS. Therefore, the supplier needs to submit a registry of sold systems and this submission needs to be verified.
3. *Verifying the operational status of the DRE system* after it has been purchased. The registered agent of the DRE system (the owner or the equipment supplier) can only claim green certificates for those systems that are operational. The operational status of the systems therefore needs to be verified.

1. Estimating average kWh production of a DRE system

The following formulas have been developed for calculating the average annual kWh production of a DRE system.

- Solar Home System: kWh production = function (system size, irradiation).
- Mini hydro system: kWh production = function (system size, demand load).
- Stand alone wind: kWh production = function (system size, demand load).

For each technology, a table containing information of kWh production per geographical region for various system sizes needs to be developed if the MMS is introduced. For the purpose of determining the transaction costs of the simplified verification procedures presented below, it has been assumed that the size of an average solar home system is 20 W_p and produces 15 kWh per year, the average size of a mini hydro system is 250 W and produces 196 kWh per year and the average size of a stand alone wind turbine is 150 W with 89 kWh production per year.

[1] In the Australian Mandatory Renewable Energy Target system decentralised systems without a meter are eligible technologies .

2. Verifying the DRE-system sales
For each technology, two options have been identified and evaluated for simplified procedures for verifying the system sales.

Solar Home Systems:

- *Option PS1: Household survey approach.* In the household survey approach the verification of photovoltaic system sales is done through a household survey of installed photovoltaic systems implemented by an independent verification team. For each participating company a random sample of photovoltaic systems sold in the past period will be drawn and will be visited. The outcome of the sample survey will then be translated to the total number of photovoltaic systems sold by the examined company. As long as certain statistical requirements for drawing sample sizes are taken into account, this approach will deliver reliable results.
- *Option PS2: Verification of financial administration of SHS companies.* Like any other company, solar companies in most countries are subject to tax payment and will need to have their financial accounts audited by an independent auditor. Since a financial auditor will also verify the sales receipts (invoices) of a company, its annual photovoltaic system sales can in principle be determined from its financial records. Hence it would require relatively little additional effort to use the same procedures for verification of photovoltaic system sales. Feedback from solar companies in other countries indicated that this system could be a viable approach. Most solar companies are being audited for tax purposes and in case they are not audited, they did not perceive it as a problem to ask for additional financial auditing.

Mini hydro installations:

- *Option HS1: Household survey approach.* As in the case of photovoltaic systems, in this model the dealers of mini hydro turbines keep a list of their customers and an independent verification team will verify the results. It became evident from other interviews that their distribution network is less wide spread and more distant than in the case of photovoltaic systems. This may hinder successful follow up of households through micro-hydro dealers. On the other hand, verification should be simple as micro-turbine users are more accessible than photovoltaic system users.
- *Option HS2: verification of financial administration of mini hydro equipment suppliers.* In the province of Sichuan, the Agricultural Machinery Bureau (AMB) is quite active in monitoring of mini-hydro units and providing O&M services. Given the potential cost synergies the AMB is included as one of the alternative verification procedures. The AMB is already maintaining a database of mini -hydro users, including system information and address information of the users, which could serve as a registration list for MMS. Users will be asked to send their address, system characteristics to AMB (preferably including a system serial number) and a copy of their sales receipt to the AMB for inclusion into the AMB customer database

Stand alone wind turbines:

- *Option WS1: Household survey approach.* The costs of household surveying have been estimated at half the costs of surveying photovoltaic systems, since users of wind are in general in easier accessible areas than photovoltaic system users.
- *Option WS2: Verification of sales through financial administration.* This activity involves the costs required to send a special accountant to verify the books of wind turbine manufacturers

3. Verifying the operational status of the DRE systems
For each technology, three options have been identified and evaluated for simplified procedures for verifying the operational status of the systems sold.

Solar Home Systems:

- *Option PP1: Household survey*. As described above under option PS1, this approach is based on a survey of a sample of at randomly selected households. The disadvantage of this approach is that the implementation costs are quite high due to the need of having a sufficiently large sample size.
- *Option PP2: Battery certification approach*. This verification approach is based on the long known fact that the battery is the weakest link in a photovoltaic system. It also is the component, which will ensure that end-users are still consuming electricity: If end-users buy a new battery for its photovoltaic system, than the photovoltaic system is still functioning and it does deserve green certificates for that revenue. A participating solar company will receive green certificates per battery it sells.
- *Option PP3: Up-front subsidy.* Monitoring of operating photovoltaic systems in the field is the most important factor, which increases transaction costs for certification of photovoltaic systems. Hence, there is likely to be an important scope for reduction of transaction costs if one of the key principles of MMS, certification after generation of kWh's has been proven, is abandoned. Instead, photovoltaic systems are subsidised upfront once the sale of a photovoltaic system has been proven. This option is very much in line with the way the NDRC REDP project hands out subsidies to solar companies in its current programme.

Mini-hydro installations:

- *Option HS1: Household survey approach.* Similar to the option PP1 a household survey could be implemented on basis of which mini hydro turbine sellers could receive green certificates for the sold mini hydro turbines. Alternatively, the Agricultural Machinery Bureau could implement through its officers an annual household survey to monitor the performance of mini-hydro systems. To minimise transaction costs the household survey should be implemented in coordination with the verifier.
- *Option HP2: Agricultural Machinery Bureau Model*. As opposed to the PV sector, the dealers of micro-hydro turbine do not play a very active role in distribution and maintaining customer relations. Instead, a government agency called the Agricultural Machinery Bureau (AMB) is filling this gap. As of 2002 the province of Sichuan through the AMB has begun an ambitious programme to improve the operations of micro-hydro systems in Sichuan. The AMB's micro-hydro model will involve the setting up of a technical service network through the AMB offices in the counties. Since the AMB would require additional funding to extend this service to all its rural counties, MMS could be a useful means to this end. AMB could offer end-users a service contract and receive their green certificates as a payment for their efforts. Depending on the amount of the MMS revenues, the AMB could be obliged to give the end-user also a down payment on spare parts.
- *Option HP3: Upfront subsidy.* Similar as option PP3 described under solar. MMS could be used to provide an upfront subsidy to micro-hydro turbines.

Stand-alone wind turbines:

- *Option WP1: Household survey*. This option is similar as option PP1 explained under solar home systems.
- *Option WP2: Battery certification approach.* This option is similar as option PP2 explained under solar home systems.
- *Option WP3: Upfront subsidy*. The same options as option PP3 explained under solar home systems.

The above 15 options for simplified procedures for verifying systems sales and system performance have been evaluated based on the following criteria:

I. *The transaction costs:* the transaction costs are the costs associated with the implementation of the verification procedures presented above. Research on transaction costs for the CDM highlights that investors will typically not support transaction costs that are more than 7% of the revenues generated by selling the carbon credits (green certificates) created by the project. As a criterion for evaluating transaction costs from a private sector a 10% threshold is taken in this study: If transaction costs exceed 10% of the green certificate revenues, costs are considered too high to make participation interesting.

II. *Robustness*: the verification procedure is considered robust if the procedure is not prone to cheating or fraud.

III. *Applicability in China*: has the procedure already been applied in China and what experience has been gained so far

The transaction costs for the verification procedures are determined, among others, by the sample size, number of companies subject to verification, frequency of verification, labour costs auditor and travel costs. Table 4.1 presents an overview of the transaction costs for each individual procedure described above and for a number of combinations of sales verification plus systems performance verification. To determine whether or not the total transaction costs meet the 10% threshold, the cost as a % of the GC price and the required multiplier to meet the threshold are also given.

Table 4.1 *Transaction costs {RMB cent/kW] for decentralised solar, mini hydro and wind systems*

		Transaction costs[2] [RMB cent/kWh]	Cost as a [%] of the GC price*	Multiplier required**
Sales verification				
Solar:	option PS1 - Household Survey	8.9		
Solar:	option PS2 - verification of financial accounts	0.6		
Hydro:	option HS1 - Household Survey	1.5		
Hydro:	option HS2 - verification of financial accounts	0.3		
Wind:	option WS1 - Household Survey	9.9		
Wind:	option WS2 - verification of financial accounts	1.2		
System performance verification				
Solar:	option PP1 - Household Survey	6.3		
Solar:	option PP2 - Battery certification	0.9		
Solar:	option PP3 - Upfront subsidy	0.5		
Hydro:	option HP1 - Household Survey	1.1		
Hydro:	option HP2 - AMB model	4.0		
Hydro:	option HP3 - Upfront subsidy	0.04		
Wind:	option WP1 - Household Survey	7.1		
Wind:	option WP2 - Battery certification	0.5		
Wind:	option WP3 - Upfront subsidy	0.3		
Total transaction costs for various combinations				
Solar:	option PS1 + option PP1	15.2	390	39
Solar:	option PS2 + option PP2	1.5	39	4
Solar:	option PS2 + option PP3	1.1	28	3
Hydro:	option HS1 + option HP1	2.6	67	7
Hydro:	option HS2 + option HP2	4.3	110	2*
Hydro:	option HS2 + option HP3	0.34	9	1
Wind:	option WS1 + option WP1	17.0	436	44
Wind:	option WS2 + option WP2	1.7	44	5
Wind:	option WS2 + option WP3	1.5	39	4

* in the case of the AMB model the threshold criterion is not 10% but 100%

[2] Transaction costs are based on a discount rate of 6%. If a discount rate of 12 % is used transaction costs expressed as RMB cents per kWh are slightly higher.

In addition to the transaction costs, the identified procedures have also been evaluated based on the robustness and the applicability of the procedure in China. The evaluation results based on these criteria are presented in Table 4.2.

Table 4.2 *Robustness and applicability of sales and performance verification procedures for decentralised PV, mini hydro and wind technologies*

Simplified verification procedure	*Robustness procedure*	*Applicability procedure in China*
Solar		
- Household survey	High if statistical requirements are applied	Difficult, but is expected to improve over time
- Verification of financial accounts	The robustness of this system is similar as with the tax audit system. Options are available to improve robustness of the procedure.	Procedure has not yet been applied in China. Financial auditing practises among solar industry needs to be more widespread
- Battery certification	Needs to be tested.	Procedure has yet to be applied. Depends on quality of financial auditing practices among solar industry in China
- Up-front subsidy	Reasonable	Feasible. There is experience with scientific photovoltaic system research in China.
Mini Hydro		
- Household survey	High.	Reasonable.
- Verification of financial accounts	Reasonably high. The robustness of this system is similar as with the tax audit system. Options are available to improve robustness of procedure.	Procedure has yet to be applied. Financial auditing practices among micro-hydro turbine sellers need to be assessed.
- AMB service model	High	Given the current initiatives of the AMB it seems feasible. Exact details needs to be further discussed with AMB.
- Upfront subsidy	Reasonable	Feasible.
Wind		
- Household survey	Reasonable	Seems feasible.
- Verification of financial account of wind turbine manufacturers	Reasonably high. The robustness of this system is similar as with the tax audit system. Options are available to improve robustness of procedure	Procedure has yet to be applied and tested.
- Battery certification	Needs to be tested	Reasonable
- Up front subsidy	Needs to be tested	Feasible.

Based on the evaluation results presented in Table 4.1 and Table 4.2 the following conclusions can be drawn with regard to the feasibility of inclusion of DRE technologies into the proposed MMS for China:

- The total transaction costs of simplified procedures for solar home systems all exceed the 10% threshold of MMS revenues but the criterion can be met if multipliers for DRE-systems are applied in the range of 3 - 39. According to the transaction costs, the battery certification combined with the up-front subsidy are the best options. On basis of robustness the sample survey option is the preferred option. With respect to the applicability in China, both the verification of the financial administration as well as the battery certification option have not yet been applied in China.

- For mini hydro installations only the upfront subsidy option meets the 10% threshold of MMS revenues. However, if multipliers in the range up to 7 are applied, all identified procedures meet this criterion. The robustness of the sample survey option and the AMB service contract option is high. With regard to the applicability in China, the sample survey and the AMB option are the most feasible options. Taken into account the transaction cost, the most preferable route would be to link the MMS scheme for mini hydro with the AMB initiative on micro-hydro as it would mean pooling of resources with the highest service for the consumer.
- None of the identified verification options for stand alone wind meets the 10% threshold of MMS revenues, but if a multiplier could be applied in the range of 4-44 these options could meet this criterion. The up-front option has the lowest transaction costs. Based on the robustness and applicability criteria, the sample survey is the best option.

5. IMPACT OF INCLUSION INTO THE MMS ON THE UPTAKE OF DRE SYSTEMS

In the previous section simplified monitoring and verification procedures for DRE systems have been presented and evaluated based on a set of criteria. The next question to address is: what would be the best MMS design option for stimulating DRE-systems and how much additional electricity will be generated annually from DRE-systems, if included into the MMS. It must be emphasised that the question here is not what is the best MMS policy instrument (feed in, tender system or RPS) but rather what provision could be made within the MMS to stimulate DRE-systems once a particular instrument (or combination of instruments) has been selected for the Chinese MMS.

The following scenarios have been analysed to determine the best design of the MMS for promoting DRE systems:

- Uniform support for grid based RE technologies and decentralised electricity production: No separate provision is made within the MMS for decentralised renewable technologies. In this scenario decentralised technologies must compete with grid based RE technologies and those eligible technologies that have lowest cost will be used to meet the MMS obligation.
- Differentiated support for grid based RE technologies and decentralised RE technologies: In this scenario DRE systems receive a higher value for the electricity produced than grid based RE technologies. This can be made operational by applying a multiplier to the number of green certificates that can be earned by electricity production from DRE systems. For example, a multiplier value of 10 for decentralised RE technologies means that the production of 1 MWh from stand alone wind is worth 10 certificates while the production of 1 MWh from grid based RE is worth only 1 certificate.

If the government sets a mandatory target for the amount or proportion of electricity that must be produced from renewable energy sources, this will create a demand for RE based electricity. This demand is fixed and independent of the cost of producing electricity from renewable energy sources and can be met by grid connected RE technologies and/or by decentralised renewable electricity systems. The producers of renewable electricity receive a premium price (which corresponds to the price of the green certificate price) to cover the costs of meeting the target. These additional costs are generally passed on to the electricity consumer.

In order to assess the impact of this premium price on the number of DRE systems installed and the amount of electricity produced, electricity supply curves have been developed for decentralised solar, hydro and wind technologies. These supply curves describe the relationship between the amount of electricity that can be produced by a particular technology at a certain level of the premium price (green certificate price). These curves are defined as follows:

Electricity Supply Curve = the cost per kWh of DRE electricity supply plus the transaction costs calculated in the previous section minus the willingness to pay of the consumer.

Based on cost figures of DRE systems that apply in China and based on estimates for the WTP for each technology, the electricity supply curves for uptake of hydro and wind and PV at different values of the multiplier is presented in Table 5.1. The assumed price of a green certificate is RMB 0.039 per kWh.[3]

[3] This price is taken from Meier (March, 2002) and corresponds to an MMS target in 2010 of 79,476 GWh produced from renewable energy sources.

Table 5.1 *Uptake of DRE in GWh/year for various multipliers, China and Sichuan, in 2010*

Multiplier	China Total [GWh]	China Hydro [GWh]	China Wind [GWh]	China PV [GWh]	Sichuan Total [GWh]	Sichuan Hydro [GWh]	Sichuan Wind [GWh]	Sichuan PV [GWh]
1	13	0	0	13	0.7	0	0	0.7
2	14	1	0	13	0.9	0.2	0	0.7
3	55	42	0	13	14.1	13.4	0	0.7
4	97	84	0	13	27.4	26.7	0	0.7
5	139	126	0	13	40.7	40.0	0	0.7
10	313	300	0	13	94.8	94.0	0	0.8
25	701	687	0	14	218.2	217.4	0	0.8
50	709	694	0	15	220.5	219.7	0	0.8
100	712	694	0	18	220.7	219.7	0	1.0
117.7	723	694	9.6	19	220.7	219.7	0	1.0

If a multiplier value of 1 is applied, each unit of electricity (usually 1 MWh) produced from renewable sources receives a green certificate, irrespective of whether the electricity is produced from grid connected or decentralised systems. In this case uniform support is provided for all types of renewable electricity production. Table 5.1 shows that in this scenario there still is some potential for decentralised PV to grow (13 GWh for China) but no new decentralised hydro and wind capacity will be installed.

If the multiplier is greater than 1, decentralised systems receive a preferential treatment. For example, if the multiplier value is 10 this means that decentralised renewable electricity systems receive 10 times more green certificates for the same amount of electricity produced than grid connected technologies. Consequently, the revenue stream for DRE systems is also 10 times larger. Table 5.1 shows that applying a multiplier of 10 will result in an additional production of electricity of 300 GWh in China compared to the scenario with uniform support.

From Table 5.1 it can be concluded that the inclusion of mini hydro into the MMS will result in a substantial additional kWh production at multiplier value of 3 or more. If mini hydro is brought under the MMS, the potential market amounts to some 727,000 new installations in China and some 234,000 installations in Sichuan province. The analysis shows that at a multiplier value of 28, the mini hydro potential of 694.3 GWh for China and 219.7 GWh for Sichuan can be fully realised.

For wind and PV very high values (more than 25) of the multiplier are needed to bring about a substantial increase in electricity production. However, a high multiplier will affect negatively the total amount of electricity produced from renewable sources and thus will jeopardise the environmental objectives of the MMS[4]. For this reasons it is recommended not to apply multipliers with a value greater than 10.

Table 5.2 presents more detailed information on the impact of including mini hydro into the MMS. For various multipliers and based on a green certificate price of RMB .039 per kWh the estimated installed capacity, electricity production and the impact on the number of poor households that get access to electricity is given in Table 5.2. Some 40 percent of the poor (with per capital income above RMB 500 per capita but below RMB 1,000 per capita) will be able to pay for mini hydro systems if a multiplier is applied of 10.3.The remaining 60 percent (including the bottom poor with per capita incomes below RMB 500) will only be able to purchase a mini hy-

[4] To clarify this point: assuming that a certificate represents 1 MWh, an MMS target of 10 MWh is met if 10 certificates have been issued. However, if a multiplier of 2 is applied for off grid technologies, 5 MWh produced by off grid is already sufficient to meet the target.

dro system if multipliers are applied greater than 10 which, as explained above, is not recommended.

Table 5.2 *Impact of different multipliers on installed capacity and the poor's access to electricity through mini hydro in China and Sichuan*

	China(All Western Provinces)					*Sichuan*				
Income level per capita	Poor households covered	Multiplier	[%] of potential market (727,000 units)	[MW]	[GWh]	Poor households covered	Multiplier	[%] of potential market (230,000 units)	[MW]	[GWh]
>RMB 500 to	0	1	0	0	0	0	1	0	0	0
<RMB 1,000	136,680	2.5	4	34.2	32.3	43,990	2.5	4	10.8	10.2
	820,060	6.4	24	205.0	193.5	263,950	6.4	24	64.9	61.2
	956,730	8.2	28	239.2	220.3	307,940	8.2	28	75.7	69.7
	1,366,760	10.3	40	341.7	317.1	439,920	10.3	40	108.1	100.3
	2,050,140	11.5	60	512.5	451.0	659,880	11.5	60	162.2	142.7
	2,665,182	15.4	78	666.3	571.6	857,845	15.4	78	210.8	180.8
<RMB 500	3,006,870	19.2	88	751.7	624.9	967,825	19.2	88	237.8	197.7
	3,143,550	20.5	92	785.9	651.7	1,011,815	20.5	92	248.6	206.2
	3,348,560	23.1	98	837.1	683.7	1,077,805	23.1	98	264.8	216.3
	3,416,900	28.2	100	854.2	694.3	1,099,800	28.2	100	270.3	219.7

In summary, the quantitative analysis on the impact of inclusion of DRE systems into the MMS on the uptake reveals that inclusion will mainly benefit mini hydro systems. If mini hydro is brought under the MMS, the potential market amounts to some 727,000 new installations in China and some 234,000 new installations in Sichuan province. The analysis also shows that a multiplier value of 1 (uniform support for grid connected and off grid RE technologies) will not result in additional new production capacity for mini hydro. Differentiated support is therefore recommended and because multiplier values greater than 10 will negatively affect the environmental objectives the recommended multiplier is in the range of 5 to 10.

The impact of inclusion of PV and small wind into the MMS on the uptake becomes significant only at multipliers greater than 100. Therefore, it can be concluded that inclusion into the MMS is not the best mechanism to promote photovoltaic and stand alone wind turbines in China.

6. POVERTY ALLEVIATION/REDUCTION IMPACTS OF DRE SYSTEMS AND MMS STRATEGY FOR THE POOR

6.1 Energy, poverty alleviation and poverty reduction

The significance of DRES for the poor is embedded in the larger question: how critical is energy as such to poverty reduction? Considerable confusion surrounds this question as yet. At one end is the view of energy as a part of the parcel of basic needs-oriented services for the poor, that is, a certain minimum amount of modern energy is deemed absolutely essential for life in the same manner that food, clothing and shelter are. Energy is thus seen as a 'life claim' and, as a result, notions like 'universal access' to electricity for basic household needs have gained recognition. At the other end is the perception of energy as a catalyst of rural economic transformations impelled by new income-earning and asset-building activities made possible to a good measure by modern energy interventions. This calls for a 'minimum plus' approach that goes beyond subsistence levels of energy consumption.

These differing views are rooted in more fundamental twists in the debate over poverty as such. By common convention, the state of being poor is defined by an income cut-off or 'poverty line', which is now acknowledged internationally as one US dollar per day per individual but tends to vary at national levels. People whose incomes fall below an established threshold are considered poor. Poverty reduction would then mean reducing the numbers of those who live below the poverty line; in other words, income growth becomes the primary measure of escape from poverty. However, the income yardstick (income poverty) has been challenged over the years for a variety of reasons whose general thrust is that there are several other factors that determine human well being - health, education, safety, security, empowerment - and they cannot be defined in monetary terms. By this definition, poverty signifies an all-round state of deprivation of which insufficient income is just one measure. This argument has invoked the notion of poverty alleviation whereby a relief, to any extent, from any of the numerous hardships the poor face is equated with a lowering of the 'intensity' of poverty by that extent. In practice though, the phrases poverty reduction and poverty alleviation are used interchangeably, which can overlook the rather different aims but equally compelling arguments underlying each.

While it is beyond the scope of this report to reconcile these differences, it is nonetheless important to grasp that poverty alleviation generally signals improvements in the living conditions of the poor without necessarily releasing them from the state of poverty as such. Such improvements mitigate the hardships of the poor and possibly render poverty less intolerable. By contrast, poverty reduction will invariably involve productive or livelihood enhancements that help people cross the poverty line by raising their incomes. One could argue that improved livelihood opportunities would, by implication, engender better living conditions, whereas the reverse is not assured.

Translating this into energy terms requires an understanding of the energy needs of the poor, which typically fall into:

- *Basic household and community needs*, such as lighting, cooking, space-heating, and essential communication and convenience. These needs are usually met by traditional energy sources (fuel wood, biomass, animal waste) and their popular modern alternatives are electricity, coal, charcoal and kerosene. The amount of modern energy services needed to meet

these needs is usually small[5] and, since they represent 'minimum' needs, there is a somewhat finite dimension to the associated energy supply capacity.
- *Productive needs*, beginning with agriculture but extending also to agriculture-related business activities (vegetables, processed fruits) and off-farm enterprises at the household and community levels. Barring indirect energy inputs (organic/chemical fertilizers, pesticides and weedicides), the direct energy needs of agricultural and enterprise activities are met by the poor through sheer human labour[6] and animal power. Replacing these with modern energy services means providing energy for motive power and heat in quantities that could be substantial and subject to increase over time. The scale of supply and the prospect of expanding supply capacity to meet rising demands, hence, become important.

6.2 Methodology

To assess the impact of inclusion of DRE systems into the MMS on the above explained two types of energy needs of the poor, the following methodology, consisting of four main stages, has been adopted:
1. Characterization of the current socio-economic conditions of the population who stand to benefit from the availability of modern energy services, particularly electricity, through DRES in Sichuan Province. This was accomplished mainly through discussions with government officials at the national, provincial, regional (Xichang) and county levels (Pingwu and Puge); and verified independently during village visits in the two counties.
2. Identification of the present energy supply-use patterns of the poor, and the social and economic impacts of DRES on them. This was carried out through focus groups in five poor villages in two designated poor counties of Sichuan Province; and the information gathered was counter-checked with county level officials of the Poverty Office and the Agricultural Machinery Bureau;
3. Assessment of the capacity and willingness to pay of the poor for DRES, and their potential responses to the kinds of MMS incentive tentatively identified by the study at the time of the village visits. This was further reviewed against more detailed data in other reports and in the context of the fuller list of MMS options eventually identified by the study.
4. Recommendations on appropriate schemes that could offer practical solutions to introduce DRE systems offering electricity to the poor. This took into account existing poverty alleviation/reduction policies and mechanisms, examined the complementarities and divergences between these and the proposed MMS options, and drew conclusions aimed at maximizing the benefits from DRES, with or without MMS.

6.2.1 Main Findings of Stage 1 & 2

Socio-Economic Conditions of the Poor

The major beneficiaries of DRES in China will largely be the poor concentrated in the Western Region who either have no access to electricity at all or whose current levels of supply insufficient. Among these are the bottom poor whose income levels are below the national poverty line and whose primary sources of energy supply are traditional fuels and human/animal labour. The socio-economic conditions of the poor in Sichuan are as follows:
- Their economic activities are centred around agriculture, animal husbandry, poultry and, occasionally, fisheries.

5 The World Energy Council estimates this to be 300 kWh per capita per annum immediately, growing at an average annual rate of 2% to 500 kWh by 2020 for electricity; and 1 toe per capita per annum for electricity and modern fuels (WEC, 2000). However, these are national averages, including both rural and urban populations. For rural populations alone, consumption levels are likely to be lower.

6 Also referred to as 'sweat energy' (IDS, 2002).

- The ecological conditions in mountain and hill areas, where the poor are concentrated, are especially harsh, characterized by limited arable land and low levels of soil fertility, with resultant low crop yields and insufficient agricultural surplus to generate cash income.
- Village and household enterprises among poor communities are generally at a low key and where they exist, they are linked largely to agricultural products, such as vegetables, fruits, poultry and fishery.
- The average income level in the poverty areas is RMB 1,250 and the average expenditure is RMB 1,000 per capita, per annum. The main items of expenditure are agricultural expenses, school fees, house rent, health care expenses, taxes and transportation costs that together take up more than 60 percent of the total. Less than 40 percent of the income is available for food and other household expenses.
- In Puge, a nationally designated poor county, the average income is considerably less, about RMB 800 per capita, per annum. Of this, only RMB 250-300 is in the form of cash, practically all of which is spent on household expenses.

Energy Supply-Use Patterns of the Poor

Ninety-seven percent of the population in Sichuan has access to electricity, including 82 percent of the 8.5 million poor in the province, either from the grid or through mini grids and isolated DRES, mainly mini/micro hydro systems. The total installed capacity of micro and mini grid hydro power in the province is 38 MW, which generates 14.2 GWh annually at a capacity utilization factor of only 4.3 percent due to poor equipment quality, low water flows and lack of service capacity. This leaves about 1.18 million poor households without access to electricity of any sort. They are located in remote mountain/hill areas and it is difficult to envisage grid supply for the vast majority of these populations since the costs would be prohibitive.

The energy and electrification status of the poor villages investigated during the present study is summarized in Table 5.2, which highlights the following facts:

- The main cooking fuels in poor rural households are fuel wood, biomass and animal waste. In two of the villages adjoining officially designated ecological zones, the villagers are restrained from obtaining fuel wood from heavily depleted neighbouring hill forests and, therefore, they use only biomass and animal waste.
- Biogas for cooking is used only in one of the villages that is connected to the grid. However, this is limited to a small proportion of about 10 percent of the households.
- Agricultural mechanization and irrigation water pumping are non-existent in four of the five villages unconnected to the grid, so there are no direct modern energy inputs to farming in them. However, chemical fertilizers, pesticides and weedicides are used in all villages.
- For the non-grid-connected villages, the main source of electricity is small hydropower. Three villages have community size plants with mini distribution grids, one of them with grid supply to a third of its households and another with isolated micro hydro units serving a fourth of its households. The remaining village has isolated micro hydro units for most of its households, with three remaining households located at a spot without water resource potential using diesel generators.
- The most recent connection was acquired by Daping village, in March 2002, and oldest connected villages were Wudaoqing (since 1985) and Xinlong (since 1982). In Daping and Hezhi (the latter electrified in 1999), households still without access to electricity form 25 and 60 percent, respectively. These are the bottom poor who cannot either afford to buy isolated micro hydro systems or pay the electricity charges for accessing the mini grid supply in place.
- In the four non-grid-connected villages, the average effective supply capacity per household is limited to a range of 40-72 W.[7] Although the installed capacity of isolated micro hydro units is between 300-3,000 W, numerous factors constrain actual generation.

[7] The typical size of photovoltaic systems owned by rural households in China tends to even smaller, at about 20 W. About 76 percent of photovoltaic systems in place are 20 W systems; 14 percent are 30-50 W; and the rest are divided between very small (<20 W) and very large (>50 W) systems.

- The low level of electricity supply per household limits applications to lighting and television mainly. With 15 W incandescent bulbs (on average, two lighting points per house) being the most popular, the quality of illumination is dismal, barely sufficient for night-time visibility and clearly inadequate for reading or writing.
- Television ownership in the non-grid-connected villages varies. While many households have colour television sets, just as many have to be satisfied with black and white sets for reasons of supply limitation. Furthermore, the high cost of television sets means not all households can afford them even if supply were not a constraint.
- Except for Xinlong, households in the other villages do not make use of any other electrical appliances, which is not surprising considering the low level of supply they receive and the economic status of the people.
- In Wudaoqing and Daping, villages with community scale mini hydro systems, the plants are connected to grain grinders/millers. In these villages, these are the only productive use applications for electricity.
- Households in all four of the non-grid-connected villages use kerosene and/or bamboo as lighting fuels. While unelectrified houses have no other choice, electrified houses fall back on these alternatives during low water season when the power supply from mini/micro-hydro systems is erratic and unreliable.
- Brown-outs are common in the Hezhi village mini grid due to low/erratic voltage even in high water seasons when the very limited supply capacity of the system is overextended by the houses simultaneously turning on television sets.

Poverty Reduction Impacts

The impacts of electricity provided by DRES on the livelihoods of the poor are low or none. In absolute terms, average annual income levels increase by around RMB 80 following electrification by mini/micro hydro systems, which is insignificant. In relative terms the economic impacts of electricity seem greater from community scale mini hydro systems than from isolated household micro hydro systems.

Table 6.1 *Energy/Electrification Status of Poor Villages in Sichuan Province*

	Yang Jia She	*Wudaoqing*	*Daping*[a]	*Hezhi*	*Xinlong*
Total no. of households	13	250	250	275	470
No. of households with access to electricity	13	250	200	165	470
No. of households without access to electricity	0	0	50	110	0
No. of years with electricity	11-May	17	<1	3	20
Electricity sources	Isolated micro hydro (10 h/h: 300 W-3 kW) Diesel genset (3 h/h)	Mini hydro mini grid[e] (10 kW)	Mini hydro mini grid[e] (159b h/h: 20 kW) grid (91 h/h)	Mini hydro mini grid (95 h/h: 8 kW) Isolated micro hydro (70 h/h: 300-600 W)	Grid
Average supply per household[c]	78 W	40 W	72 W	42 W	-
Main electrical appliances:					
- Incandescent bulb		15-40 W	15-60 W	15-60 W	40-100 W
- Radio	15-25 W	Yes	Yes	Yes	Yes
- TV (black & white)	Yes	Yes	Yes[d]	Yes	Yes
- TV (colour)		Yes	Yes[d]	Yes[d]	Yes
- Hi-fi	Yes		Yes[d]		Yes[d]
- VCR					Yes[d]
- Clothes iron					Yes[d]
- Drinking water heater					Yes[d]
- Washing machine					Yes[d]
- Grain grinder/miller		Community plant[e]	Community plant[e]		
Other DRES used					Solar water heater[d]
Lighting fuel substitutes/supplements	Kerosene	Kerosene, bamboo	Kerosene, bamboo	Kerosene, candles	Biogas h/h unit[d]
Main cooking fuels	Fuel wood	Biomass, animal waste	Biomass, animal waste	Fuel wood, biomass, animal waste	Fuel wood, biomass, biogas

[a] Study data covers only 55 households of Group 4 of the village with small hydro mini grid.
[b] Includes 100 households from adjoining village.
[c] Based on actual generation efficiency.
[d] Owned only by very small minority of affluent households.
[e] Owned by one or a few households as business enterprise.

The real issue, however, is not whether or not DRES can reduce poverty. Rather, the question is on what scale and level of reliability can DRES be promoted so that they cater for new or enhanced livelihood activities. At their present scale and level of reliability, they can meet a part of the basic and social needs of the poor, but not all such needs. If this could be changed, then DRES can play a more significant role in the future in both poverty alleviation and poverty reduction, especially since the remote poor communities in China have few other energy options.

Poverty Alleviation Impacts

The assessed impacts of electricity on the living conditions of the poor in the study villages are summarized in Table 6.2.

Table 6.2 *Perceived Benefits of Electrification in Study Villages in Sichuan Province*

	Yang Jia She	*Wudaoqing*	*Daping*	*Hezhi*	*Xinlong*
Lighting	Very high	Very high	Very high	Very high	Very high
Knowledge of outside world through TV	Very High	Very high	Very high	High	Very high
Household/community safety	High		Low	High	High
Opportunities for social interaction	High				
Savings in women's time			Very high		High
Savings in men's time	Low	Very high	Very high		
Education:					
- additional study hours	None		Moderate		
- knowledge gain through TV	Moderate			High	
Ease of cooking, household activities					
Income growth	Insignificant	Low	Too early to tell	Insignificant	Low

6.2.2 Main Findings of Stages 3 & 4

Affordability of DRES

Data from the study indicate that the poor cannot afford the initial investment DRES from their own resources. Low income was cited as the foremost constraint to DRES at all levels of government that were consulted during the study. The assessment of the economic status of the study villages shows that the average poor household with access to electricity through mini/micro hydro systems takes informal loans[8] to bear the initial investment in DRES.

In spite of this, many poor households have managed to acquire DRES one way or another which indicates their willingness to pay. But willingness can obscure the underlying desperation that often drives the poor in their quest for electricity. In three of the villages covered by the present study, the mini/micro hydro systems were acquired through borrowings from family and friends. Only in one instance, the community scale system was purchased through a bank loan, which was repaid within three years out of earnings from the attached grain grinding facility. This underlines the importance of not only financing, but also of the effectiveness of productive uses of electricity in ensuring the financial sustainability of DRES.

Willingness to Pay

The most common measure of people's willingness to pay for electricity is their current expenditure on other forms of energy that electricity can replace. According to Puge County officials, the household expenditure on kerosene for lighting ranges between RMB 15-20, which works out to an annual expenditure of RMB 240-300, an amount equivalent to the cost of a 300 W micro hydro system spread over 3-4 years but requiring a much longer payback period of 7-9 years for a 40 W_p solar home system. However, data from the village visits indicates an annual household expenditure on kerosene and candles of only RMB 2. The possible explanations are that the

[8] From family and friends. Indications are that these loans are on a 'repayable when able basis' or offset by in-kind labour or other non-cash reciprocal means.

latter pertain to unelectrified households that are not really the bottom poor or that poor households in the villages covered by the study use other sources of energy, such as bamboo, for lighting.

Table 6.3 *Economic Status of Study Villages in Sichuan Province (RMB)*

	Yang Jia She	*Daping*	*Hezhi*	*Xinlong*
Annual Household Income				
Farming (grains, vegetables, fruits)	1,000	2,050	2,100	4,800
Livestock, poultry, fishery	1,000	110	650	1,200
Other (including food for work)	400			
Total income	*2,400*	*2,160*	*2,750*	*6,000*
Annual Household Expenditure				
Farm expenses (mainly chemical fertilizers)	400	600	1,000	1,000
Food	1,040	1,050	1,050	2,000
Education	860		860	1,230
Hospitality, recreation		300		
Clothing	40	100	55	300
Transportation, communication (phone)				120
Medical care, medicine	50	16	15	150
Taxes	20	22	27	60
Electricity O&M expenses/charges	100	50	100	210
Kerosene, candles	2		2	
Other				
Total expenditure	*2,512*	*2,138*	*3,109*	*5,070*
Annual Surplus/Deficit	-112	22	-359	930
As [%] of Annual Income	5	1	13	15
Average Household Assets (mainly house and livestock)	8,000	6,000	6,000	8,000

What is important here is that the average poor household is barely able to make its ends meet and expenses on electricity (O&M costs of DRES equipment) are a significant portion of its cash outflow. For instance, in Yang Jia She, the average O&M expenses on isolated micro hydro systems is RMB 100 per household. If the costs of common appliances and replacement components were taken into account, the financial situation of poor households will be affected even more. The cost of a 21” colour television set (RMB 1,200) exceeds the cost of investment in a 300 W micro hydro unit and the cost of a replacement battery (RMB 520) every two years for a 40 W_p solar home system is equivalent to the cost of the latter’s ten-year life cycle, effectively doubling it.

Potential Future Role of DRES for the Poor

In spite of the mixed evidence presented in the preceding section, it is clear that DRES will play a distinct role in providing modern energy services, particularly electricity, to the remaining poor in China. The study suggests the following future strategy to promote DRES:

- In order to overcome the central constraint of affordability, a two-pronged approach, simultaneously targeting system cost reduction and purchasing power increase, seems essential. MMS could contribute towards the former.
- Efforts to increase the poor’s purchasing power to acquire DRES are ideally linked to the promotion of DRES. This could take the form of projects or mechanisms that combine the sale of DRES with the sale of productive use appliances that carry the potential for income-enhancing micro enterprises or other similar activities at the household level. This, however, is subject to the availability of complementary inputs.
- For the bottom poor, that is, those with incomes below the national poverty line, neither cost reduction, nor income enhancement may be on a scale sufficient to enable them to acquire DRES in the near term. In their case, all or a major portion of the initial investment may

have to be sourced from public and/or international funds, with a potential role for MMS in the latter.

- In either case, the scale of DRES and the quality of electricity services provided by them should improve substantially upon present capacity and performance levels. In Sichuan, small hydropower will remain the main DRES for electricity in the future. According to provincial government officials, systems below 1 kW capacity are capable of meeting only the basic needs of the poor. In order to cater for productive uses, the focus for the future should be on systems in the 1-10 kW range, with an emphasis on community scale systems. Greater attention should be paid to increasing the generation from these systems and efforts undertaken to improve their technical reliability.
- Scaling up system capacity and/or ensuring performance quality should not be restricted to new systems sold but it should also cover the upgrading of systems already in place. In fact, rehabilitation programmes are already in motion and these should be continued and expanded alongside market penetration measures for new systems.
- Other forms of DRES, such as biogas, and efficient end-use devices like improved cook stoves should be included in future promotional efforts as they are essential to achieve significant time savings among the poor women. Biogas also has the potential to generate a substantial reduction in chemical fertilizer costs, which is equivalent to raising incomes.
- The allocation of public investment to support DRES acquisition should have greater specificity in relation to the poor. The present practice of allocations by county may need to be replaced by new arrangements that are able to ensure priority to poor villages and/or poor households as measured by income level.
- On the whole, if poverty reduction is the end objective, then the future role of DRES should be guided by this objective in form and substance. A poverty reducing promotional model will then assume primacy over the present basic needs model, which tends to concentrate on small and static system capacities. It would be necessary to redirect attention to larger systems with modularity and expansion potential to cater for demand growth over time.

7. RECOMMENDATIONS

In the previous sections the feasibility of including DRE systems into the MMS have been analysed and evaluated based on the following set of criteria:

1. Transaction costs: if the transaction costs for monitoring and verification procedures for DRE systems are more than 10% of the expected MMS revenues, costs are considered too high (too much money is spent on procedures) and a more direct way of promoting DRE systems is recommended.
2. Robustness of verification procedure.
3. Applicability of verification procedures in China.
4. Impact of inclusion of DRES into the MMS on the additional number of DRE systems sold.
5. Impact of inclusion of DRES on poverty reduction and poverty alleviation.

Before a nation-wide MMS scheme will be introduced in China, the proposed MMS will first be tested in a pilot phase at provincial level. Recommendations regarding the inclusion of mini hydro, PV household applications, PV village power and stand-alone wind turbines into the MMS pilot are presented below.

7.1 Mini-hydro

The recommended verification procedure for mini-hydro is the household survey approach both for sales verification as well as for verification of system performance. This verification procedure can be combined with the Agricultural Machinery Bureau service contract model. The evaluation results for mini-hydro are as follows:

- The total transaction costs of the recommended monitoring procedure are less than the 10% threshold of total expected MMS revenues at relatively low multiplier values of 7 or higher.
- The robustness of the recommended survey approach for monitoring and verification of the systems is high if statistical requirements are applied.
- The applicability of the survey approach for mini-hydro systems combined with the maintenance service contract is very good. The Agricultural Machinery Bureau is deemed to play an essential role in the implementation of this option. The Bureau is well established, is already involved in the development of mini hydro systems and has expressed its willingness to conduct maintenance activities in the framework of the MMS. This makes this option very attractive from a practical point of view.
- There is a large potential market for new mini hydro installations in China (estimated potential is approximately 727,000 systems) in general and in Sichuan in particular (estimated potential is approximately 234,000 systems). At a multiplier value of 10.3, 40% of the total mini-hydro potential will be developed in China as a result of inclusion into the MMS. This corresponds to some 290,800 new systems in China with an estimated total annual electricity production of 317.1 GWh (nearly 0.4 % of the proposed MMS target of 79,476 GWh in 2010 by P. Meier).
- As indicated above, at a multiplier value of 10 the access of the poor to mini hydro systems will increase by some 290,800 systems. On average each system connects 4.7 households, which means that some 1.37 million households will gain access to electricity if mini hydro is brought under the MMS. This is approximately 24% of the total number of households currently without electricity. The poverty analysis revealed that mini hydro in most cases positively impact on poverty alleviation, although historically the impact has been negatively affected by low quality equipment, resulting in higher repair and maintenance costs and a higher percentage non-performing systems. Mini hydro can also contribute to the creation of economic activities although the evidence found during the village visits did not show any cash savings arising from these economic activities. This means that mini hydro

does not yet strongly contribute to poverty reduction in the sense of asset and income creation, probably because the system sizes are often too small for these applications. If mini hydro is included into the MMS, incentives will be provided for better system design and better maintenance.

Based on the above considerations it is recommended to include mini-hydro in the pilot phase of the proposed MMS for China because the evaluation results are positive for all identified criteria. It is further recommended to provide differentiated support for mini hydro and grid connected RE technologies and to apply a multiplier for mini hydro in the range of 5-10. Higher multiplier values would jeopardise the environmental objectives of the MMS.

7.2 Photovoltaic household applications

The recommended verification procedure for PV household applications is the verification of financial administration of solar companies because the other identified verification options are too expensive and do not meet the 10% threshold criterion. The evaluation for PV household applications is as follows:

- A multiplier value of 4 would be enough to meet the 10% threshold for the transaction costs of the recommended monitoring and verification procedure.
- The robustness of the recommended procedure is reasonable and is similar to the robustness of the tax audit system. Options are available to improve the robustness of the procedure.
- Applicability of the recommended verification procedure is highly questionable. Although linking the verification of sales registration with the tax system is a very innovative and at first glance attractive option, it is questionable whether the current status of the tax system in China is sufficiently well established and reliable to be used for verifying system sales. The fact that presently a large percentage of the smaller companies pay a fixed amount of tax independent of sales turn over makes this option also less attractive to apply within the pilot phase of the MMS. More research is first needed to assess the willingness of the tax authorities to co-operate with the MMS authority in order to avoid problems relating to fraud and double counting of certificates before this verification option can be implemented.
- To achieve a significant uptake of photovoltaic systems under the MMS a multiplier value of about 77 is required which is, as explained in Chapter 5, not recommendable because such a high multiplier would negatively influence the environmental objectives of the MMS. A multiplier value of 10 would result in some 30,000 additional PV systems for China which is only 1.4 % higher compared to the base case.
- The impact on poverty PV concerns mainly the improvement of the living conditions of the poor and to a much lesser extent PV creates direct income generating activities. However, PV systems could have a indirect impact on income generation by allowing more study in the evening.

Based on the above evaluation it is recommended not to include PV for household applications into the MMS pilot because the applicability of the recommended verification procedure in China is questionable and because the impact on the uptake of PV is very limited. The funds available for the promotion of photovoltaic systems can better be used in a more direct way.

7.3 PV village power

At present, some 50 villages in Sichuan and some 1,000 villages in China receive electricity from a mini grid powered by photovoltaic installations. These are isolated systems but are metered and therefore do not need separate verification procedures and thus can be incorporated into the MMS pilot with relatively low transaction costs. Based on an identified potential of 20,000 villages that could be supplied through these systems and an average production of

4,080 kWh per system the maximum achievable production amounts to 81.6 GWh (0.1% of the MMS target).

Because the electricity produced by PV mini grids is also for productive use, the poverty impact is positive both in terms of improving the living conditions of the poor as well as in the creation of new economic activities which could lead to broader sustainable local development.

Based on the above considerations it is recommended to include PV village power mini grid systems into the MMS. It is further recommended to provide differentiated support for PV village power and grid connected RE technology and to apply the same multiplier value as for mini hydro.

7.4 Stand alone wind turbines

The recommended verification procedures are the financial administration of wind turbine manufacturers for monitoring the number of systems sold and the battery certification approach for motoring the system performance. The evaluation results based on the set of criteria presented above are as follows:

- The proposed verification procedure meets the 10% threshold if a multiplier value of 5 would be acceptable.
- The robustness/applicability of the battery certification procedure for monitoring system performance is unclear. This proposed procedure is new and has not been applied in China or in any other country. The procedure therefore needs to be tested first.
- The potential market for new systems is confined to a limited number of provinces with enough wind resources availability. The quantitative analysis shows that although there is a large potential market for small wind systems, this market can only be tapped at very high values of the multiplier. For example, a market penetration of 30 % can be reached only if a multiplier of 123 is applied which is unrealistically high.
- The poverty impacts of small wind systems are comparable to PV household applications. The impact on poverty is mainly related to lighting and communication.

Based on the above considerations it is recommended not to include stand alone wind systems because the robustness and applicability in China of the proposed verification procedures is questionable and because the impact on the uptake of small wind systems is substantial only at very (unrealistically) high values of the multiplier. The MMS therefore is not a suitable mechanism to promote small-scale wind systems.

8. OUTLINE FOR THE DESIGN OF A MINI HYDRO MMS PILOT PHASE IN SICHUAN PROVINCE

In this Chapter the mini hydro option, the recommended option for inclusion into the pilot phase of the MMS, will be further elaborated. A tentative estimation of the costs related to the implementation of this option in the province of Sichuan is presented.

As explained in Section 4.3, if mini hydro is brought under the MMS an essential role is envisaged for the Agricultural Machinery Bureau with regard to the implementation of this option. The main responsibility of the AMB is to manage the agricultural machinery sector. This involves policy formulation and implementation, formulation of technical standards, quality control and technical research management in the agricultural sector.

The AMB is part of the government at national, provincial and county level. In the province of Sichuan the AMB in an independent department but in some other provinces the AMB falls under the Ministry of Agriculture. The AMB in Sichuan employs some 50 professional staff and is in charge of the management of mini hydro (under 10 kW).

The Sichuan government has allocated RMB 220 million in the 10th five-year plan to support the poor people in getting access to electricity by installing and maintaining mini hydro installations. This is achieved by preparing an annual plan and by quality control of mini hydro equipment and projects. The average capacity of the installed mini hydro is 1 kW. The size of the new systems installed in Sichuan tends to be relatively big; most systems are in the range of 3-5 kW and each system supplies electricity to some 10 households.

Although the mini hydro programme developed by the Sichuan government is very ambiguous, it will not be able to provide electricity to more than 10% of the estimated 1.1 million households in Sichuan who are currently without electricity. Additional funding from the MMS therefore could further expand this programme.

The costs related to the inclusion of mini hydro into the pilot phase of the MMS comprise three main components:

1. Costs related to developing of capacity in the AMB.
2. Costs related to the development of MMS institutions.
3. Costs related to the development of awareness campaign.

In Table 8.1 an overview of the estimated costs is presented for the various cost components described in the previous section. It must be emphasised that these estimates are only rough indications of the various cost items based on the experience gained in Europe with establishing MMS institutions. The purpose of the overview is to provide a first indication of the order of magnitude of the costs of setting up a mini hydro MMS pilot in Sichuan. A more detailed estimation that also takes into account the specific circumstances in China can only be made after the decision on the MMS pilot has been taken and the specific modalities of the MMS have been defined. A second point that needs to be stressed concerns the fact that the costs are related to the inclusion of mini hydro and not the establishment of the MMS itself.

Table 8.1 *Indicative costs for mini hydro MMS pilot in Sichuan*

	Costs [× 1,000 RMB]
Initial establishment of the mini hydro MMS body	
- Drawing up of the statutes for the mini hydro body	50
- Development of standards and procedures	100
- Development of registry	600
- General costs for the establishment of the mini hydro MMS body	50
- Unforeseen	100
Yearly running costs for the mini hydro MMS body	
- Verification process (option HS1+option HS2)	2,600*
- Issuing of approximately 100,000 certificates	1,242**
- Redeeming of consumed certificates	1,242
- Updating of the standards and procedures	80
- Management/reporting	150
- Green Certificates payments: 100,000 certificates @RMB 39	3,900
Building of capacity in the AMB	
- Development of MMS administration system	200
- Technical assistance	400
Development and implementation of an awareness campaign	250

* It is expected that the amount needed for verification will decrease significantly over time as the sample size will decrease and also the frequency of verification will be lower.

** Based on fees applied by the Dutch RECS office.

APPENDIX A LIST OF POSSIBLE DRE OPTIONS

Table A.1 *PV*

System no.	System type	Device
1	Up to 4 W (DC)	Lighting, one 5 W DC light
2	4 - 10 W (D/C)	One 9 W light
3	10 - 20 W (D/C)	Two lights
4	20 - 40 W (D/C)	Two lights, black&white TV
5	40 - 50 W (D/C)	Two lights, black&white TV
6	50 - 100 W (A/C)	Colour TV
7	100 - 200 W (A/C)	Colour TV, lights, satellite receiver
8	200 W - 2000 W	Hotel, shop, restaurant
9	5kW-100 kW	Mini grid(control room, battery room, centralised PV arrays)
	Hybrid home systems	
10	100 W wind/50 W PV	
11	300 W wind/100/200 W PV	
12	Up to 500 kW(2.3 wind-1/3 PV)	Village power

Table A.2 *Mini hydro systems*

System no.	System type	Device
13	Up to 1 kW	Supplies one household
14	1-5 kW	2-5 households
15	5-10 kW	5-10 households
	> 10 kW	Connected to the grid

Table A.3 *Wind*

System no.	System type	Device
15	Up to 50 W	2-3 lights & one black-white TV set
16	50 - 100 W	2-3 lights & one colour TV set
17	100 - 150 W	Same with above & one small refrigerator
18	150 - 200 W	2-3 lights & one colour TV set and middle size refrigerator
19	200 - 300 W	2-3 lights & one colour TV set & large size refrigerator
20	300 - 500 W	Same as above, plus pumping system
21	500 - 600 W	Same as above
22	600 W - 1 kW	Several households use
23	1 - 2 kW	Several households use
24	2 - 3 kW	Village power system
25	3 - 5 kW	Village power system
26	5 - 6 kW	Village power system
27	6 - 10 kW	Village power system